PCT
WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G06F 3/14, 17/30

A1

(11) International Publication Number: WO 98/52119

(43) International Publication Date: 19 November 1998 (19.11.98)

(21) International Application Number: PCT/US97/09256

(22) International Filing Date: 16 May 1997 (16.05.97)

(71) Applicant (*for all designated States except US*): THE TRUSTEES OF COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK [US/US]; 116th Street and Broadway, New York, NY 10027 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): CHANG, Shih-Fu [-/US]; Columbia University, Dept. of Electrical Engineering, 500 West 120th Street, New York, NY (US). SMITH, John, R. [US/US]; Apartment 15B, 275 West 96th Street, New York, NY 10025 (US).

(74) Agents: TANG, Henry et al.; Brumbaugh, Graves, Donohue & Raymond, 30 Rockefeller Plaza, New York, NY 10112 (US).

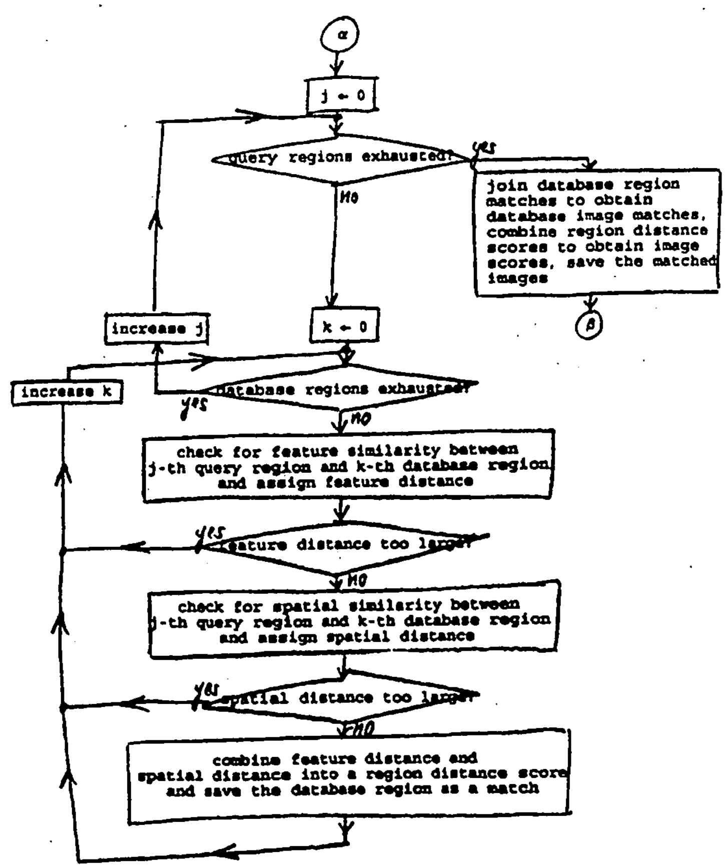
(81) Designated States: CA, JP, US.

Published
With international search report.

(54) Title: METHOD AND SYSTEM FOR IMAGE RETRIEVAL

(57) Abstract

In a system in which database images are represented by regions having specified feature attributes and spatial location attributes, image queries can be directed to region feature similarly and region spatial location similarity in combination. If desired, the relative spatial arrangement of regions can also be taken into account.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece	**ML**	Mali	**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**MN**	Mongolia	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MR**	Mauritania	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MW**	Malawi	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MX**	Mexico	**US**	United States of America
CA	Canada	**IT**	Italy	**NE**	Niger	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NL**	Netherlands	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NO**	Norway	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NZ**	New Zealand	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**PL**	Poland		
CM	Cameroon	**KR**	Republic of Korea	**PT**	Portugal		
CN	China	**KZ**	Kazakstan	**RO**	Romania		
CU	Cuba	**LC**	Saint Lucia	**RU**	Russian Federation		
CZ	Czech Republic	**LI**	Liechtenstein	**SD**	Sudan		
DE	Germany	**LK**	Sri Lanka	**SE**	Sweden		
DK	Denmark	**LR**	Liberia	**SG**	Singapore		
EE	Estonia						

METHOD AND SYSTEM FOR IMAGE RETRIEVAL

Technical Field

This invention relates to computerized image retrieval and, more specifically, to retrieval based on image database querying.

Background of the Invention

With advances in computer hardware technology, it has become possible to store, manipulate and transmit large numbers of images. When represented in computer-tractable form, the images can be included in an image database.

Systems have been developed, typically in the form of computer software, for image database management and image retrieval. For example, as disclosed in U.S. Patent 5,493,677, issued February 20, 1996 to Balogh et al., images can be retrieved by searching text associated with the images for a match with a query.

Systems have also been developed which use image content descriptors, for querying by image content. Such a system is disclosed in U.S. Patent 5,579,471, issued November 26, 1996 to Barber et al. and in the paper by W. Niblack et al., "The QBIC Project: Querying Images by Content Using Color, Texture, and Shape", in *Storage and Retrieval for Image and Video Databases*, Wayne Niblack, Editor, Proc. SPIE 1908, pp. 173-187 (1993).

Summary of the Invention

We have recognized that, for greater accuracy in retrieving images from an image database, querying based on image content can be combined with querying based on spatial location. Thus, in a system in which each image is represented by a plurality of regions

having feature attributes and spatial location attributes, queries can be directed to region feature similarity and region spatial location similarity in combination. If desired, the relative spatial arrangement of regions can also be taken into account.

Brief Description of the Drawing

Fig. 1 is an example of an image with regions for inclusion in a database.

Fig. 2 is a tabular display of a representation of the regions of Fig. 1.

Fig. 3 is an example of an image with regions for database querying.

Fig. 4 is a tabular display of a representation of the regions of Fig. 3.

Fig. 5 is a flow diagram of database query processing for discriminating based on region feature and region absolute spatial location.

Fig. 6 is a flow diagram of database query processing for discriminating based on the relative location of regions.

Detailed Description of Preferred Embodiments

The following description is primarily in terms of method steps for execution by a suitable processor under program control. The program may originate as software, or, for greater efficiency, it may be embodied at least in part in dedicated firmware or hardware.

A prototype system embodying features as described has been formulated in the JAVA language. The system can operate on suitable hardware such as a SUN Workstation, a Silicon Graphics Workstation, or a PC with a Pentium processor, for example.

Conveniently, an image database to be queried has tabular form, with each record or table entry

representing a region of an image. A record includes an image identifier, a region identifier, a region attribute and, for geometric characterization, the x- and y-coordinates of the centroid of the region, the width and height of the region, and the area of the region. The table may be generated by manual keyboard entry based on visual inspection of images. Alternatively, if a suitable pattern recognition system is available, table generation may be automated.

To illustrate database entries, the image 10 shown in Fig. 1 and having been given the identifier "T" can be represented by the table entries shown in Fig. 2. Included are:

region 100 (t_0, stretching across the bottom of the image, below a broken line);

region 101 (t_1, bounded by a rectangle drawn with broken lines);

region 102 (t_2, bounded by a rectangle drawn with chain-dotted lines),

region 103 (t_3, bounded by a rectangle drawn with broken lines); and

region 104 (t_4, stretching across the top of the image, above a broken line).

The x,y-coordinates, the width w, and the height h of each region are given in percent of the respective maximal values. The values x, y, w and h define a "bounding rectangle" for each region, so that the area of a region is less than or equal to w times h. As illustrated, regions may overlap, and their union need not cover the image.

The attribute f may simply represent color, for example, with color being represented by known means, e.g., by a color histogram or by color sets. Other simple attributes which may be used include texture and shape, and such attributes may be combined into more

complex attributes.

A search query is expressed correspondingly. For example, for the search pattern shown in Fig. 3, a query region table may be formed as shown in Fig. 4.

For a database and a query, e.g. with entries as illustrated by Figs. 2 and 4, respectively, Fig. 5 illustrates query processing for finding database entries based on the query. The general aim is to find images that contain arrangements of regions similar to those in the query.

According to Fig. 5, starting at "α", for each region in the query, the database regions are searched for a feature match (step 51) and a spatial match (step 52). For spatial matching, this involves using a suitable metric for comparing the spatial information such as x, y, h, w and area of the query region with the corresponding information for the database regions. Suitable metrics include Euclidean distance and other Minkowski distances, and quadratic metrics whose definition involves a square matrix which expresses the relative similarity between the components of a vector. A metric can also include weights which may be different for each of the geometric parameters.

Similar metrics can be used for feature matching (f_i). For example, if color histogram information is included in terms of components "red", "green" and "blue", a 3-component Euclidean metric can be used. Analogously, this applies when such information is included in terms of components "hue", "saturation" and "intensity".

For efficiency, as shown in Fig. 5, thresholds are applied to the computed feature and spatial distances. Thus, if a distance exceeds the threshold, the database region is not included for further consideration. Instead of, or in addition to using

separate thresholds for spatial and feature similarity as shown in Fig. 5, thresholding can be applied also to the combined region distance or score, i.e. before saving a region match in step 53. Distances may be combined by simple addition, or by suitable weighting followed by addition, for example.

If multiple processors are available, "k-loop" feature similarity processing analogous to step 51 and spatial similarity processing analogous to step 52 may be carried out in parallel instead of pair-wise sequentially as illustrated in Fig. 5. Parallel processing then yields two sets of regions, namely (i) those which meet feature similarity regardless of spatial similarity, and (ii) those which meet spatial similarity regardless of feature similarity. Thus, to obtain the desired set of regions which meet both types of features, a "join" operation will be required. After joining, a final thresholding operation can be performed. Advantageously, multiple processors may also be used for parallel processing within steps 52 and 53.

Image matches are obtained as a result of the "join" operation in step 54, producing all those database images which meet each one of the region requirements of the query. A query may result in an image being saved in step 54 more than once, namely for different combinations of its regions which satisfy the query. Such multiplicity may be helpful to a user of the system; otherwise, duplicates can be deleted by a simple one-pass search of the saved images.

If the relative spatial location or arrangement of regions is not important to a user, the computation may terminate at this point (β), though preferably after the saved images are sorted by score.

For discriminating further based on relative spatial location of regions, a process can be used as

illustrated by Fig. 6, using so-called 2-D strings. Generation of 2-D strings at this point, i.e. after similarity processing, may be termed "query-time 2-D string generation".

For a query image, a 2-D string includes the x-coordinates of the centroids of the regions, arranged as an increasing sequence, followed by the y-coordinates of the centroids, also arranged as an increasing sequence. For a database image, correspondingly, the coordinates of those regions are used which were matched against the query image regions.

The 2-D string of the query image is formed in step 61, and, in step 62, this string is matched against the 2-D strings from each of the saved images. In step 63, only in case of a match, the database image is saved, so that only those images are ultimately sorted and produced in step 64 which have a 2-D string which matches the 2-D string of the query image.

Instead of or in addition to 2-D strings including x- and y-coordinates of centroids as described, 2-D strings can be produced after rotation of the coordinate system, e.g. by 45°. Such 2-D strings are defined analogously, using coordinates x' and y' of the centroids in the rotated coordinate system.

CLAIMS:

1. A method for retrieving image representations from an image database, comprising:

for each of a plurality of regions of a query image, searching the database for image regions which match the query region with respect to at least one feature similarity and at least one spatial similarity; and

joining the matched image regions.

2. The method according to claim 1, wherein, in searching the database, feature similarity and spatial similarity of the database image regions are ascertained pair-wise sequentially.

3. The method according to claim 1, wherein, in searching the database, feature similarity and spatial similarity are ascertained using separate processes in parallel.

4. The method according to claim 1, further comprising saving those database images which include the joined image regions.

5. The method according to claim 4, further comprising sorting the saved images.

6. The method according to claim 4, further comprising discriminating among the saved images based on relative location of the joined regions.

7. The method according to claim 6, wherein discriminating among the saved images comprises comparing 2-D strings.

8. The method according to claim 7, wherein the 2-D strings comprise x- and y-coordinates of region centroids.

9. The method according to claim 7, wherein the 2-D strings comprise x'- and y'-coordinates of region centroids, in a rotated coordinate system.

10. The method according to claim 6, further comprising sorting the discriminated images.

11. The method according to claim 4, further comprising deleting duplicates from the saved images.

12. The method according to claim 1, wherein the feature similarity comprises color similarity.

13. The method according to claim 1, wherein the feature similarity comprises texture similarity.

14. The method according to claim 1, wherein the feature similarity comprises shape similarity.

15. A system for retrieving image representations from an image database, comprising:

means for searching the database, for each of a plurality of regions of a query image, for image regions which match the query region with respect to at least one feature similarity and at least one spatial similarity; and

means for joining the matched image regions.

16. The system according to claim 15, wherein the means for searching the database comprises means for

ascertaining feature similarity and spatial similarity of the database image regions pair-wise sequentially.

17. The system according to claim 16, wherein the means for searching the database comprises means for ascertaining feature similarity and spatial similarity in parallel.

18. The system according to claim 15, further comprising means for saving those database images which include the joined image regions.

19. The system according to claim 18, further comprising means for sorting the saved images.

20. The system according to claim 18, further comprising means for discriminating among the saved images based on relative location of the joined regions.

21. The system according to claim 20, wherein the means for discriminating among the saved images comprises means for comparing 2-D strings.

22. The system according to claim 21, wherein the 2-D strings comprise x- and y-coordinates of region centroids.

23. The system according to claim 21, wherein the 2-D strings comprise x'- and y'-coordinates of region centroids, in a rotated coordinate system.

24. The system according to claim 20, further comprising means for sorting the discriminated images.

25. The system according to claim 18, further

comprising means for deleting duplicates from the saved images.

26. The system according to claim 15, wherein the feature similarity comprises color similarity.

27. The system according to claim 15, wherein the feature similarity comprises texture similarity.

28. The system according to claim 15, wherein the feature similarity comprises shape similarity.

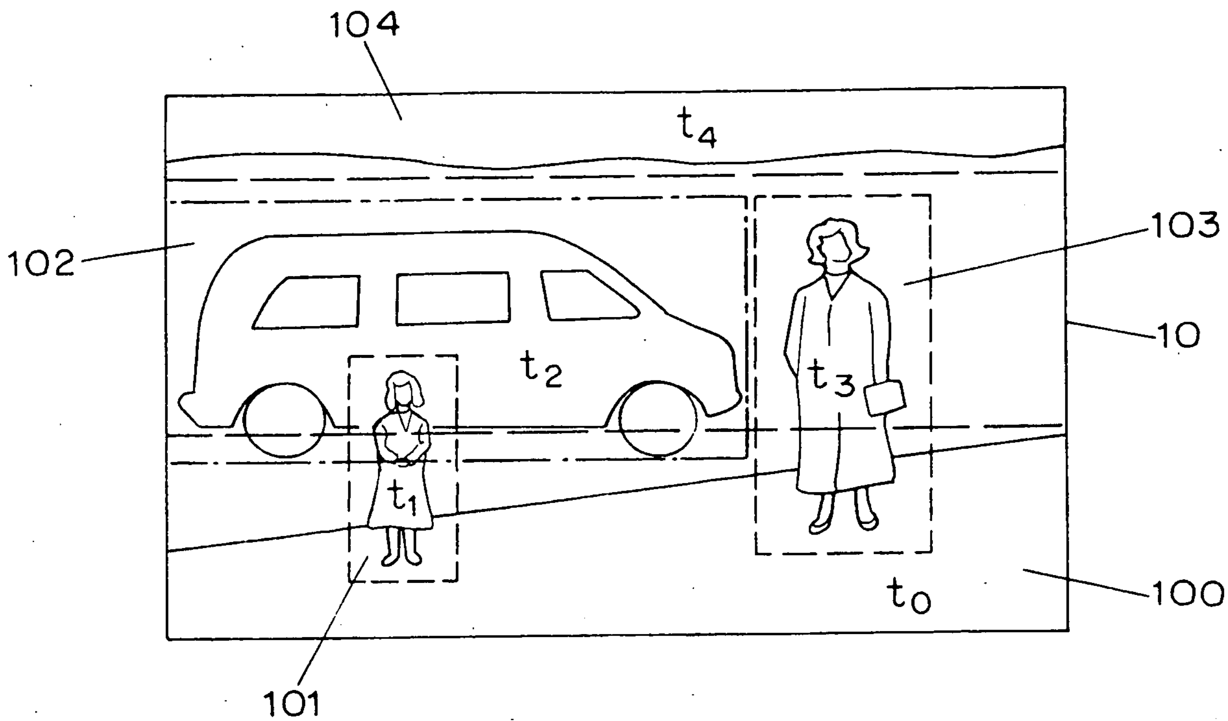


FIG. 1

IMID	REGID	f	x	y	w	h	AREA
T	t_0	f_0	50	80	100	40	3000
T	t_1	f_1	25	60	10	55	500
T	t_2	f_2	35	45	60	50	2000
T	t_3	f_3	75	55	20	80	1200
T	t_4	f_4	50	10	100	20	1500

FIG. 2

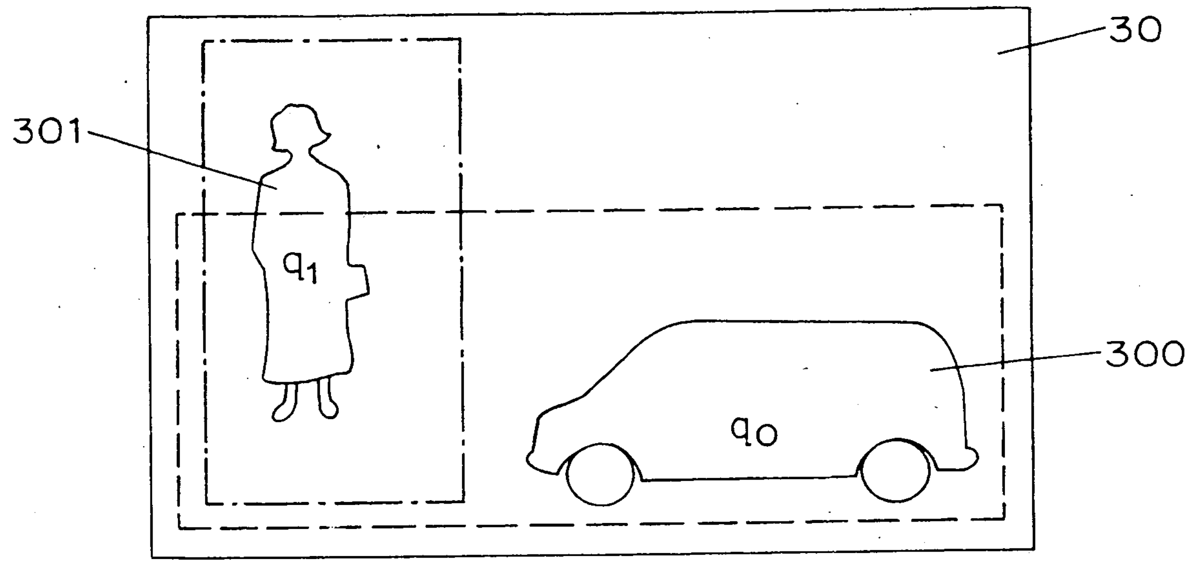


FIG. 3

IMID	REGID	f	x	y	w	h	AREA
Q	q_0	f_0	20	50	20	80	1000
Q	q_1	f_1	70	65	50	40	1500

FIG. 4

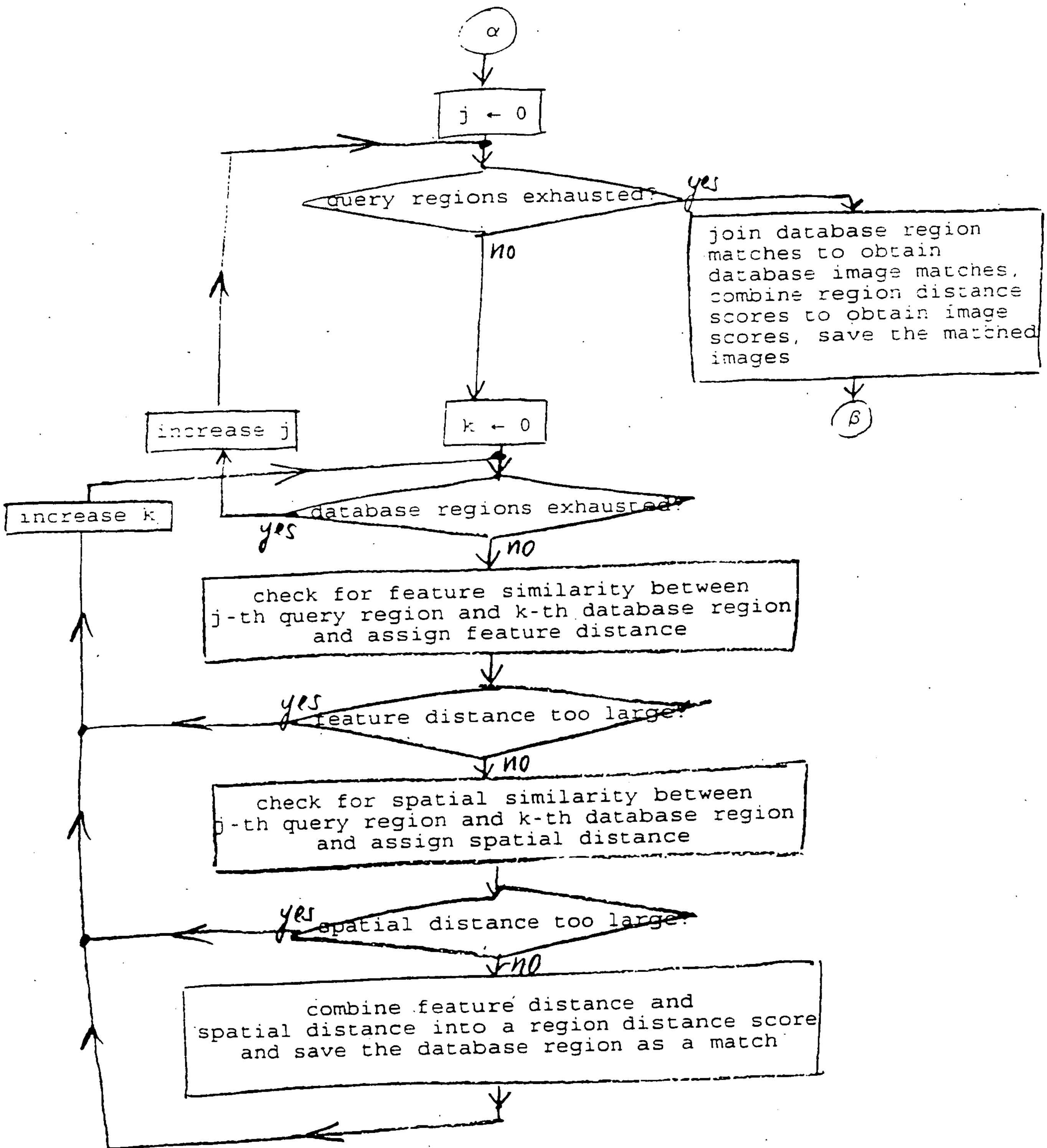

α
j ← 0
query regions exhausted?
yes
no
join database region matches to obtain database image matches, combine region distance scores to obtain image scores, save the matched images
β
increase j
k ← 0
increase k
database regions exhausted?
yes
no
check for feature similarity between j-th query region and k-th database region and assign feature distance
yes
feature distance too large?
no
check for spatial similarity between j-th query region and k-th database region and assign spatial distance
yes
spatial distance too large?
no
combine feature distance and spatial distance into a region distance score and save the database region as a match

Fig. 5

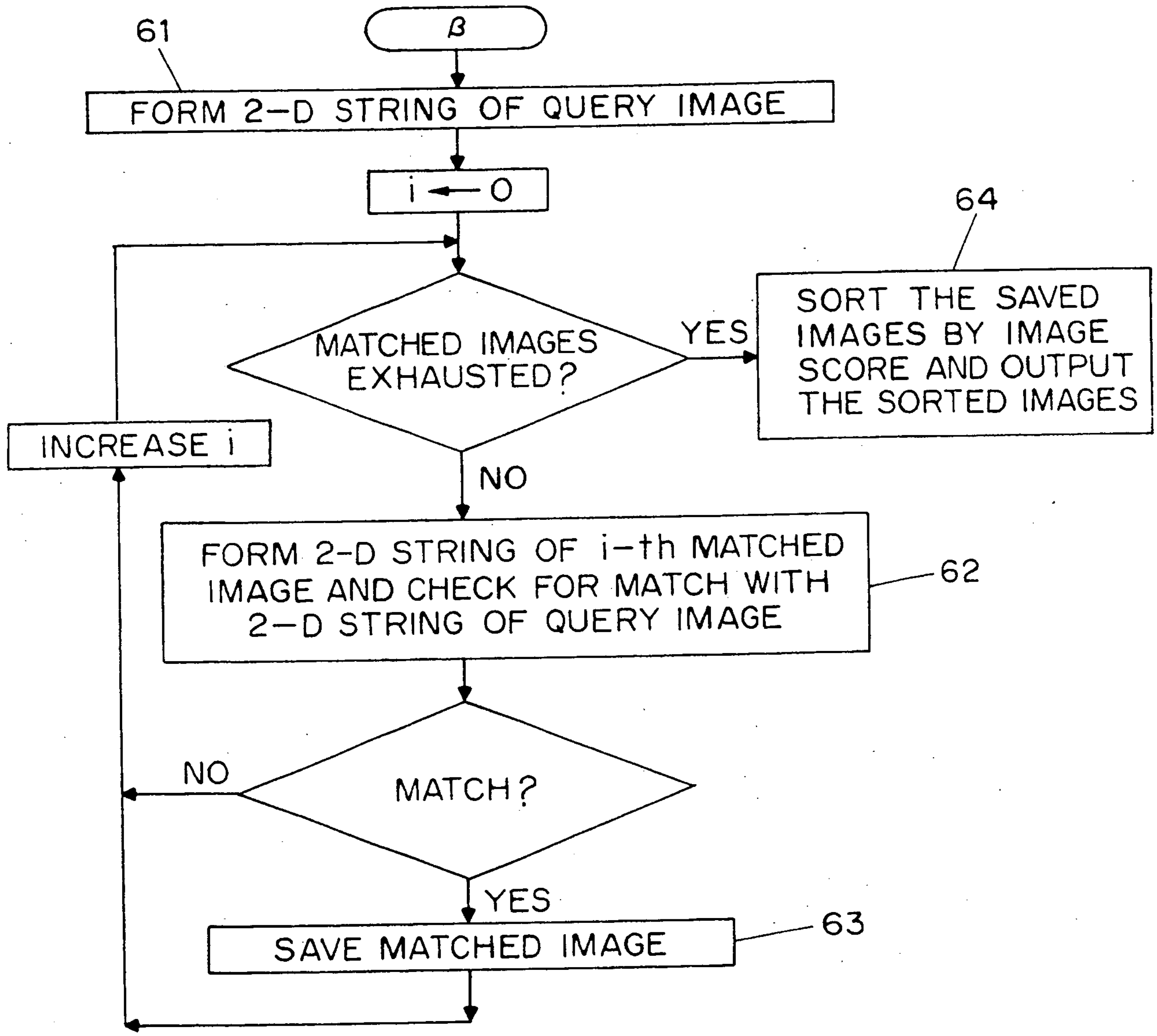

β
61
FORM 2-D STRING OF QUERY IMAGE
i ← 0
64
MATCHED IMAGES EXHAUSTED?
YES
SORT THE SAVED IMAGES BY IMAGE SCORE AND OUTPUT THE SORTED IMAGES
INCREASE i
NO
FORM 2-D STRING OF i-th MATCHED IMAGE AND CHECK FOR MATCH WITH 2-D STRING OF QUERY IMAGE
62
NO
MATCH?
YES
SAVE MATCHED IMAGE
63

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/09256

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06F 3/14, 17/30
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 396/326, 339, 340, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,546,572 A (SETO et al.) 13 August 1996, col.1, lines 15-36, col.7, lines 5-11.	1-4, 6, 12-18, 20, 26-28
Y	US 5,557,728 A (GARRETT et al.) 17 September 1996, col.2, lines 53-68, col.3, lines 1-17.	1-4, 6, 12-18, 20, 26-28
Y	US 5,428,774 A (TAKAHASHI et al.) 27 June 1995, col.3, lines 51-68, col.4, lines 1-40	1
Y	US 5,493,677 A (BALOGH et al.) 20 February 1996, col.1, lines 56-68, col.2, lines 1-16	1
Y	US 5,615,112 A (LIU SHENG et al.) 25 March 1997, col.4, lines 65-68, col.5, lines 1-68, col.6, lines 1-68, col.7, lines 1-27	1

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 JULY 1997	26 SEP 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	THOMAS BLACK
Facsimile No. (703) 305-3230	Telephone No. (703) 305-9707

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/09256

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,617,119 A (BRIGGS et al.) 01 April 1997, col.1, lines 60-68, col.2, lines 1-20	1

Form PCT/ISA/210 (continuation of second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/09256

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

396/326, 339, 340, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615